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Astronaut Operations Requirements Document for the White Light Coronagraph Experiment S-052 for the Apollo Telescope Mount

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PREFACE

Pilot-astronaut and scientist-astronaut observers will be involved in the Skylab missions. This manual presents information necessary for successful performance of the observers' function in the White Light Coronagraph portion of the Apollo Telescope Mount experiments.

The coronagraph was designed at the High Altitude Observatory of the National Center for Atmospheric Research under NASA Contract NAS5-3950 and built by Ball Brothers Research Corporation under subcontract NCAR-48.

This document has been rewritten to reflect the latest information on experiment operations; the revisions do not contain any major changes in experiment design or operations philosophy. No further revisions will be made to this document.

CONTENTS

FIGURES

I. SCOPE OF EXPERIMENT

The preflight, in-flight, and post-flight operations required to perform the S-052 White Light Coronagraph Experiment (WLCE) for the Apollo Telescope Mount (ATM) are described. A discussion of the scientific objectives of the experiment and a brief description of the hardware are given. Details on the experiment system and subsystem are given in Ref. 1; the experiment commands, displays, and the interface between the spacecraft and experiment are given in Ref. 2; and the configuration of the film camera and latching mechanism for the WLCE is given in Ref. 3.

II. EXPERIMENT OBJECTIVES

In the past, knowledge of the solar corona has been severely limited by the paucity of observations of the intermediate and outer coronal regions--regions where the coronal gas is accelerated to become the solar wind and coronal streamers become clearly identifiable. The many photographs (Figs. 1 through 3) that have been made during the period of totality of solar eclipses represent only a glimpse of a particular coronal configuration, essentially unrelated in time. Figures 1 and 2 are photographs made during totality of 31 August 1932 and 25 February 1952, respectively, and are representative of the coronal form near solar minimum. Figure 3 is a photograph of the corona on 7 March 1970, taken using a graded filter to suppress the inner coronal brightness so that forms can be traced near the limb.

Numerous yet unsolved problems have been defined by past research, including:

- What is the three-dimensional structure and form of coronal streamers?
- What is the correlation between the formation and temporal evolution of streamers and surface features?
- What is the spatial variation of the solar wind in the corona?
- What are the optical counterparts of the various coronal radio bursts, and what mechanism triggers them?

The principal objectives of the WLCE are (a) synoptic observation of the solar corona during the ATM mission, and (b) observation of transient coronal phenomena that may be associated with coronal radio bursts and solar activity. The high angular resolution capability of the WLCE will allow unprecedented detailed examination of the density structure of the corona during the entire Skylab mission and, for the first time, will allow quantitative specification of the electron density into the region of the corona where closed magnetic structures exist. The achievement of these goals is a necessary first step toward a solution of the above problems, and should provide a general understanding of the synoptic behavior of the corona.

III. OBSERVATIONAL MODES AND MODE SELECTION

A. AVAILABLE MODES

To achieve the experiment objectives, the WLCE will photographically monitor the coronal brightness and polarization from 1.5 to 6.0 solar radii from the center of the solar disk at a wavelength band extending from 3500 to 7000 Å. In normal operation, the WLCE employs four operational modes to achieve the experiment objectives. (An additional mode is available for use on a contingency basis; see Sect. V-E). The five modes, described below, are summarized in Table 1.

Table 1

ATM CORONAGRAPH MODE DESCRIPTION

Mode	Frame Rate[a]	Polarizers	Duration of Mode	Frames per Sequence
Standard patrol	12 every 5 min 30 s	Sequenced	5 min 30 s	12
Extended standard patrol	12 every 5 min 30 s	Sequenced	16 min 12 s	36
Continuous patrol	3 every 82.5 s	In clear position	Until manually stopped	Variable
Fast scan	3 every 40.5 s	In clear position	16 min 12 s	72
Secondary programmer	3 every 64 s	In clear position	Until manually stopped	Variable

[a]All modes are exposure-sequenced.

The *standard patrol* mode consists of three different exposure durations (3, 9, and 27 s) at four different polarizer positions (three polarized at 120° to each other and one unpolarized), thereby expending 12 frames. The exposure durations and polarizer positions are automatically sequenced and the mode is automatically terminated after 5 min 30 s, when the 12 exposures have been made. Figure 4 is the shutter control wave form for the *standard patrol* mode.

The *extended standard patrol* mode consists of three *standard patrols*; the three are automatically sequenced so that the observer does not have to activate a *standard patrol* mode after each 5 min 30 s. The *extended standard patrol* mode automatically terminates after 16 min 12 s (36 frames). Figure 5 is the shutter control wave form for the *extended standard patrol* mode.

The *continuous patrol* mode provides pictures at the rate of three frames every 82.5 s. The exposure duration is sequenced through the three different durations (3, 9, and 27 s), while the polarizer wheel is locked in the clear (no-polarizer) position. This mode must be terminated manually by the observer. Figure 6 is the shutter control wave form for the *continuous patrol* mode.

The *fast scan* mode takes pictures at the maximum rate possible: three frames every 40.5 s. Exposure durations are cycled, but again the polarizer wheel is locked in the clear position. This mode automatically terminates after 16 min 12 s (72 frames) of operation. Figure 7 is the shutter control wave form for the *fast scan* mode.

If the instrument is taking data in any mode and the observer chooses to change to any of the other modes, the mode select switch is so configured that any change in switch position automatically initiates a stop command.

The *secondary programmer* is used only if the primary programmer fails (see Sect. V-E). The *secondary programmer* takes three frames every 64 s using exposure durations of 2, 6, and 18 s. The polarizer is locked in the clear position, and the mode must be terminated manually. Figure 8 is the shutter control wave form for the *secondary programmer* mode.

Standard patrol and *fast scan* may be selected by ground command, and *fast scan* can, on ground command, interrupt the *standard patrol*.

B. EXPERIMENT PROGRAMS AND MODE SELECTION

The selection of a particular observational mode is dictated by the particular coronal problem under investigation. Eight programs have been selected to provide data on specific coronal problems. In order to accomplish these eight programs for the coronagraph and the multitude of associated programs for the other ATM experiments, a series of Joint Observing Programs (JOPs) has been established. Table 2 provides a list of the JOP numbers with their corresponding topics of solar study. Optimal operation of the ATM experiments to provide correlative data for the JOPs requires a sequence of experiment observations which are designated Building Blocks (BBs). Table 3 provides a list of Building Block numbers and the solar phenomena each BB is designed to observe. Table 4 shows the Building Blocks used to provide observations for each Joint Observing Program. (For a more detailed discussion of BBs and JOPs, see Ref. 4.) Table 5 gives the distribution of primary observing time among the principal observing programs.

Table 2

JOINT OBSERVING PROGRAMS

JOP-1	Study of the chromospheric network and its coronal extension
JOP-2	Active regions
JOP-3	Flares
JOP-4	Prominences and filaments
JOP-5	Constant-latitude studies
JOP-6	Synoptic observations of the sun
JOP-7	Atmospheric extinction
JOP-8	Coronal transients
JOP-9	Solar wind
JOP-10	Lunar libration points, lunar calibration
JOP-11	Chromospheric oscillations and heating
JOP-12	Program calibration

Table 3

BUILDING BLOCKS

BB-1	Synoptic observations--sun centered
BB-2	Corona
BB-3	Quiet sun--spatial resolution--faint objects
BB-4	Spatial and spectral resolution--bright features
BB-5	Spatial resolution--bright objects
BB-6	Spectra
BB-7	Spatial resolution--bright objects
BB-8	Flare
BB-9	Limb flare
BB-10	Pre-flare--high time resolution
BB-11	Spectra
BB-13	Limb study
BB-14	Corona background study
BB-15	Atmospheric extinction
BB-16	Coronal transients--fast
BB-17	Coronal transients--slow
BB-18	Chromosphere oscillations
BB-19	Velocities
BB-22	Calibration
BB-23	Active limb study

Table 4

Building Block Usage Summary

S-052 Operates X No.

Joint Observing Program Number	Building Blocks																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1			X			X					X		X										
2		X		X	X	X	X			X			X	X					X				X
3								X	X														
4		X	X			X					X			X									
5		X				X					X		X										
6	X	X									X												
7															X								
8										X						X	X						
9	X	X																					
10	X	X																					
11		X								X								X					
12	X					X				X	X		X			X						X	

Table 5

PRIMARY OBSERVING TIME DISTRIBUTION

Joint Observing Program	Building Block Number	Mode Repetition Rate for one Complete Program	Program Duration	Program Should Start	Remarks
Synoptic Observations[(a)] (JOP-6)	1,2	Four per day manned Two per day unmanned	Entire mission	Every 12 ±2 h	
Solar Wind (JOP-9)	2	One per orbit for 30 sunlit orbits	Two days	At the convenience of the observer	
Coronal Transients (JOP-8)	16, 17	Three per orbit for two consecutive orbits	Two orbits	Immediately after start of limb phenomena	
Coronal Transients (JOP-8)	17	Three per orbit for two consecutive orbits	Two orbits	Following onset of burst	Information that Type II or Type IV burst is in progress to be transmitted from ground
Coronal Transients (JOP-8)	Observer's option	N/A	N/A	Following visual identification	
Flares (JOP-3)	16, 17	One per orbit	One orbit	At the convenience of the observer	Observer activation of successive extended patrol sequences
Lunar Libration (JOP-10)	2	One per orbit for eight orbits	Seven to eight orbits	At start of favorable libration occultation	Lunar libration program depends on suitable launch date
Active Regions (JOP-2)	2	Per ATM update instructions	N/A	See JOP-2	Information of presence of active region on limb to be updated from ground

(a) Daily patrol figures assume one manned operation of 28 days and two of 56 days each, plus two periods of unmanned operation, one each at 56 and 28 days.

The *synoptic observations* program (JOP-6) assesses the development of coronal forms during the entire mission; it is to be performed two times per day with the coronagraph pylon approximately in polar alignment, and two times per day with the pylon equatorially aligned. The program employs the *standard patrol* in Building Block 1 (BB-1) so that the synoptic development of the coronal electron densities may be studied quantitatively. The program is initiated every 12 ± 2 h. It is highly desirable that additional *standard patrols* be activated each two hours whenever possible; the coronal forms may then be studied in great detail during limb passage.

The *solar wind* program (JOP-9) permits a detailed search for the passage of coronal material outward to form the solar wind, and requires the initiation of the *standard patrol* (BB-2) once per orbit for 30 consecutive orbits. Thus, material whose characteristic velocity is on the order of 10-20 km/s can be observed on passage through the coronagraph field of view. The requirements of this JOP may be satisfied with unattended operation, but due to the random orientation of the pylon, this is not desirable.

The *coronal transients* program (JOP-8) is the first of the "opportunistic" type programs, and is used to study the passage of coronal material or shock fronts as a result of the occurrence of either a radio burst or limb activity (limb flare, surge, eruptive or spray prominence, disappearing filament). There are several options possible, depending upon the phenomenon occurring:

a. Immediately following a Type III radio burst, limb flare, surge, eruptive prominence, or disappearing filament, a *fast scan* (BB-16) is to be initiated, to allow observation of phenomena whose characteristic velocity is about 10^5 km/s. Following the *fast scan* sequence, successive *extended standard patrols* (BB-17) are to be initiated to complete the current orbit, and the entire next orbit. Thus, material or shock fronts whose characteristic velocity is about 10^3 km/s can be followed through the WLC field of view.

b. Following a Type II or Type IV radio burst, and in the case where no correlative disk event has been noted, successive *extended standard patrols* (BB-17) are to be initiated throughout the current orbit, and the entire next orbit.

c. In the case where visual inspection of the WLC television monitor indicates changes occurring in the corona, any operational mode that is appropriate to the time scale of the phenomenon is to be initiated at the option of the observer.

The *lunar libration* program is designed to determine whether interplanetary material has collected at the Lagrangian points of the moon-earth system. The *standard patrol* (BB-2) is activated in each of nine orbits, centered about the passage of a Lagrangian point through the WLCE field of view. The times of passage will be known before launch.

The WLCE also participates in the observations of the coronal aspects of active regions (JOP-2) through the initiation of several *standard patrols* (BB-2) when the active region of interest is near limb passage. This will be especially appropriate prior to east limb passage of selected active regions. These observations will normally be specified via the ATM update instructions to the crew.

Finally, flares which occur within 45° of the limb (4.7 arc min) may be identified prior to the event as limb flares. When these occur, a single sequence of *fast scan* is to be activated in BB-9, and followed by repetitions of *extended standard patrol* throughout the current orbit and the entire succeeding orbit.

IV. DESCRIPTION OF EXPERIMENT

The equipment for the WLCE comprises an externally occulted Lyot coronagraph (Fig. 9); the design is dictated by the need to reduce the instrumentally scattered light to levels on the order of $10^{-10}B_{\odot}$, where $B_{\odot}$ is the mean solar radiance. The optics housing contains the Lyot section of the coronagraph (Fig. 10), the function of which is as follows. Light incident upon the primary objective, O_1, is brought to a focus and occulted by an internal disk, D_4. The infinity focal plane is refocused on the film plane by the Lyot objective, O_2. Light diffracted by the primary objective aperture is blocked by focusing the aperture outside the aperture of O_2. This is accomplished by the field lens, F_1. The remaining instrumental stray light has its origin in scattering (surface and internal) at the primary objective, and this component is substantially reduced (about 10^{-4}) through the use of a series of three external occulting disks which shield the primary objective lens from direct sunlight. The stray light incident upon the primary objective is thrice diffracted around the edges of the three external occulting disks which are supported by a pylon that blocks approximately 15% of the coronal data.

The external occulting disk assembly and the optics housing are affixed to an optical bench mounted on the ATM spar. The space between the front of the optics housing and the external disk assembly is enclosed in a light-baffle tube, and the experiment film camera is located on the side of the optics housing. To prevent thermal imbalance, a heat-dumping mirror on the front of the optics housing forms a low quality solar image between the external occulting disks and the light tube to reflect solar heat back into space. A TV camera is mounted on the top of the optics housing and a semi-passive *thermal control system* maintains critical instrument structures at essentially a uniform temperature.

A. OPERATIONAL BACKGROUND INFORMATION

From an operational standpoint, the WLCE consists of a thermal shield aperture door, pointing error sensor, internal occulting disk alignment error sensor, thermal control system, television camera, electronics subsystem, and film camera. Actual operation of the experiment consists primarily of actuating and monitoring these systems, which are described in detail below.

The *thermal shield aperture door* (see Fig. 10) protects the experiment from contamination and micrometeoric impact and protects the front of the experiment from extreme heating from the heat-dumping mirror when the ATM is in an offset pointing mode. Actuation of the aperture door is normally a manual operation, but the door will close automatically if the pointing error of the experiment exceeds approximately 5 arc min from sun center or if the operating power is turned off while the door is still open. Also, the ATM system will automatically close the aperture door if the door is open when Skylab moves into the dark portion of the orbit. If the pointing system should fail and continually supply an erroneous pointing error signal to close the door, a manual override is available. The aperture door cannot be opened until the experiment power is turned on.

A schematic diagram of the experiment pointing reference system is shown in Fig. 11. The *pointing error sensor* consists of four silicon cells which detect the location of the shadow of the external occulting disks on the primary objective lens aperture. The outputs of diametrically opposed cells are subtracted and any asymmetry of cell illumination produces a cell output which is amplified and presented to the observer as the experiment pointing error. Systems tests indicate the output is a linear function of the error angle over a range of ±17 arc min, and the center pointing position (zero cell output) is repeatable to within ±13 arc sec. A maximum pointing error of 30 arc sec will automatically terminate operation of the film camera if the experiment is in the data-taking mode.

The *internal alignment sensor* functions electrically in the same way as the *pointing error sensor*. Optically, a target aperture in the tube of the external occulting disk assembly is imaged on the internal occulting disk by the primary objective lens. Direct sunlight enters the external occulting disk tube and is filtered by an infrared filter with short wavelength cutoff of 0.75 μm (7500 Å) before passing through the system. Proper alignment of the internal occulting disk, D_4, is accomplished by moving the disk until the infrared image is centered on the four silicon cells mounted on the internal occulting disk. Systems tests show that the output of the system is a linear function of error angle over a range of ±6 arc min, and the centering of the D_4 disk is repeatable to within ±5.4 arc sec. The internal occulting disk alignment system is a closed loop servo system which automatically centers the internal occulting disk during normal operating conditions. If the servo system should fail, a manual override is provided which allows the D_4 disk to be centered manually. (The manual system is discussed in more detail in Sect. V-E.)

The *thermal control system* consists of an array of panel heaters mounted on the experiment to control the optical housing and optical bench temperature to 21 ±4°C (70 ±6°F) and to remove temperature gradients across the optics housing. The entire heater system is actuated by a single off-on switch on the control panel. Each heater panel is a closed system sensing and controlling its own temperature. Each panel also incorporates a fail-safe mode which turns the panel off if power is continually applied and overheating occurs. Experiment temperature should be between 4 and 21°C (40 and 70°F) before the *thermal control system* is turned on; otherwise the experiment may be damaged due to differential temperature stressing.

The *television system* (see Fig. 10) provides unique backup capabilities for some of the automatic experiment systems and for improving the quality of the data through direct observations. Prime objectives of the TV system are to:

- Provide a backup for the alignment of the internal occulting disk
- Provide a backup for pointing the experiment
- Allow monitoring of contamination in the experiment line of sight
- Allow monitoring of the corona for visible changes and to adjust the observing programs accordingly to optimize the data

The *TV system* utilizes a low-light-level camera at the image plane and presents a coronal image to the observer at the monitor. The camera has a square raster and, since the photocathode is somewhat smaller than the complete coronal image, the TV image will be only 4.5 solar diameters. Figure 12 is a copy of the 1970 eclipse photograph that has been purposely degraded in resolution to match the resolution capability of the *TV system*--approximately 30 arc sec.

The coronal image is deflected to the TV camera by a movable mirror in the main beam, thereby prohibiting simultaneous use of the *TV system* and the *film camera*. Control of the movable mirror is manual, but if the mirror is left in the TV position and the *experiment programmer* is then initiated the mirror will automatically move into the *film camera* position after the first exposure. If for some reason the mirror command system fails and the mirror jams mechanically, the observer can manually remove the mirror on the next EVA. (Manual removal of the mirror is discussed in Sect. V-E.) The TV camera is protected from direct sunlight by moving the mirror automatically to the camera position when the experiment pointing error exceeds 5 arc min.

The *electronics subsystem* comprises a power supply and a programmer. The power supply, which features 100% redundancy, provides closely controlled power for instrument operation. The programmer provides the automatic observational modes described in Sect. III-A. A secondary programmer provides partial redundancy (also described in Sect. III-A). Other control functions described herein are provided via the *electronics subsystem*.

The *film camera* is a 35-mm sequential camera (Fig. 13). The *film camera* (Fig. 10) is sealed with an internal nitrogen atmosphere at 40% relative humidity and 5.2 psia to protect the film and mechanism. Four cameras will be used in the mission, and all four will be preloaded with Kodak Special Film 026-02. The observer exchanges entire cameras three times during EVA and retrieves the final camera but is not required to handle film at any time. Figure 14 shows the camera installed on the experiment. (Replacement of cameras is discussed in Sect. V-C.) The camera and latching mechanism configuration is specified in Ref. 3.

V. OPERATION OF THE EXPERIMENT

The coronagraph experiment operates only when the ATM is pointed at the center of the sun. The experiment *pointing error sensor* will automatically stop any data accumulation sequence if the coronagraph pointing error exceeds a maximum of 30 arc sec; it will automatically close the external door when the pointing error exceeds a maximum of 7 arc min. Both discriminators can be overridden via the automatic door override switch.

A. CONTROLS, DISPLAYS, AND OPERATIONS

Standby power and heater power are turned on when the ATM is first activated, and both remain on at all times except during EVA for camera exchange.

Two consecutive *fast scan* sequences will be taken on each film camera before any other data are accumulated and just prior to film removal. This portion of film will be used for processing tests before the remaining film is developed.

The observer will be required to record the ATM fine sun sensor readout each time the coronagraph is aligned to the center of the sun within 20 arc sec. This recording will be done primarily on voice tapes so that the bias offset can be tracked on the ground, thereby allowing coronagraph operation using the fine sun sensor if the coronagraph pointing error system should fail for any reason.

B. CONTROL AND DISPLAY PANEL DESCRIPTION

The coronagraph controls on the control and display panel are given below. The numbers following the experiment controls correspond to the control numbers on the S-052 portion of the control and display panel shown in Fig. 15. A detailed experiment activation and deactivation sequence is given in Ref. 5.

Main Power Switch (1)

A three-position latching switch supplies a pulse to latching relays that provide power to S-052 "operate" or "standby" or both. The main power switch will be at "standby" to allow monitoring of temperature monitors during the initial portion of unmanned or unattended operation.

Door (2) and Indicator (3)

A three-position switch, with the two outer positions momentary contact, provides an input to the ATM aperture logic to "open" or "close" the door. The aperture door may be opened when main power is on. Turning power to off or standby issues a command to close the door. Associated with the door switch is an indicator which provides door status information.

Auto Door (4)

A two-position latching switch allows a pulse to pass from the S-052 to the ATM aperture logic to automatically close the aperture door should the pointing error of the experiment exceed 7 arc min, the +10-V S-052 power fail, or the ATM issue a "night" signal while the switch is in the "normal" position. With the switch in "override," the status of the door is not affected by the pointing error, the power supply, or the ATM "night" signal.

Mode (5)

A 12-position rotary switch is used to select a command line to start *standard patrol, extended patrol, continuous patrol, fast scan,* or *secondary programmer*. The command is issued when the "start" switch is actuated. The position of the rotary switch is not pertinent until the "start" switch is depressed. Appearance of the "operate" light (9) indicates that a program has been initiated and is in operation. Initiation of the "operate" light is delayed until the first frame of film is exposed and advanced. A sequence-complete indicator provides mode-complete status for the *standard, extended standard,* and *fast scan* modes.

Low Film Inhibit (6)

The "low film inhibit" is a two-position latching switch that allows the observer to override an automatic inhibit of the *fast scan* mode. With the switch in the "normal" position, the *fast scan* mode cannot be activated after the "frames-remaining" (7) indicator shows that 95% of the film has been expended. In the "override" position this inhibit is blocked. Note: The low film inhibit "override" is to be used only when sufficient film remains to meet daily synoptic observational requirements or when solar activity warrants jeopardizing synoptic observations.

Frames Remaining (7)

The "frames-remaining" indicator provides visual indication of film usage.

Start, Stop (8)

The "start, stop" switch is a two-position momentary switch.

Ready/Operate (9)

The "ready/operate" signal is an indicator of experiment status. Lack of an indication that the experiment is ready to accumulate data will not inhibit experiment operation if the "start" command is initiated. However, initiation of the "start" sequence will automatically move the TV mirror after the first exposure if it is in the main beam.

Thermal (10)

A two-position latching switch supplies a pulse to latching relays that provide S-052 *thermal control system* power.

Sequence Complete (11)

The "sequence-complete" signal is a *positive* indication that an experiment mode has been successfully completed. A *negative* indication after the experiment has been activated in an automatically terminated mode indicates that an experiment mispoint has stopped experiment operations or that a mode has been manually stopped.

Mirror Position (12)

Commands to position the film camera/TV camera mirror are provided by a three-position switch. The outer positions of the switch are momentary contact.

Scale - X10 (13)

A two-position latching switch controls the scale factor of the pointing meter. The meter (16) scale can be switched from X1 (0-30 arc sec) to X10 (0-300 arc sec).

Align (14)

A three-position latching switch provides commands to the pointing meter to display the *pointing error sensor* output in the "pointing" position and to display the "internal alignment sensor" output in the "disc auto" and "disc man" positions. In "disc man" power is also applied to the MODC (15) switch for manual commands and a command is issued to inhibit the automatic operation of the D_4 positioning mechanism. When the switch is positioned in "disc man," S-052 will remain under manual control until the switch is moved from "disc man" and instrument power is removed and reapplied, thereby resetting the instrument logic.

MODC (Manual Occulting Disc Controller) (15)

Manual control of the D_4 mechanism is provided by a five-position switch. Four of the positions are momentary and are positioned at the four quadrants of the switch.

Manual control of D_4 is required if the automatic internal occulting disk alignment should fail. Switch 14 allows the astronaut to override the automatic system with a manual system, and Switch 15 is the manual alignment control for the internal occulting disk.

WLC Align (16)

The "WLC align" indicator provides pitch and yaw display of the experiment pointing error or of internal misalignment. The cross pointers remain centered at null position in the absence of error signal voltages.

C. CAMERA REPLACEMENT

One camera will be installed on the experiment at launch and three others will be available for replacement during the mission. The observer must change cameras three times during the mission and retrieve the final camera. Figure 16 shows the film camera with handle and lens cover in place.

Figure 17 shows the camera installed on the coronagraph experiment. The launch lock holds the camera latch mechanism lever in the engaged position during launch and must be released by pulling straight out when removing the first camera. The latching mechanism lever is then pulled down to another mechanical stop. Pulling down on the latching mechanism lever will move the film camera down, thereby disengaging the film camera electrical connector and freeing the film camera for removal. Detents hold the camera in this position until the observer is ready to grasp the handle and pull the camera straight out. A tether ring (see Fig. 16) is provided on the camera handle for tethering the camera during further EVA operations.

Figure 18 shows the experiment ready for camera installation. A removable face cover is provided to protect the lens and electrical connector; the cover must be removed before camera installation. Extreme caution must be exercised to insure that the camera lens is not scratched or contaminated between cover removal and installation. The replacement film camera is installed by pushing the film camera straight in toward the experiment until it reaches a mechanical stop and pushing the latch mechanism lever upward again until the lever hits a mechanical stop. Actuation of the launch lock is no longer required after the first camera is removed. The cameras containing exposed film are then returned to the orbital assembly for storage until they are returned to earth.

The cameras shall not be opened at any time and shall be returned to the Principal Investigator for film extraction and processing.

D. UNATTENDED AND UNMANNED OPERATIONS

The coronagraph experiment can be operated by RF commands from the ground during sleep periods or other periods when the ATM control and display console is unattended. Table 6 lists the commands available for operation of the coronagraph from the ground stations. The ground digital address system (DAS) must be actuated prior to control and display panel closeout for unattended or unmanned operation.

During the unattended and unmanned portions of the Skylab mission the coronagraph experiment can be operated only in the *standard patrol* or *fast scan* modes and no downlink television will be possible. The switches for the coronagraph experiment on the control and display panel must be preset to the configuration shown in Table 7 to allow operation of the experiment during unattended and unmanned portions of the mission; the RF commands given in Table 6 enable ground command of the experiment under these conditions.

E. CONTINGENCY OPERATIONS

If one of the coronagraph experiment systems should fail, the contingency operations identified below will allow continued operation of the experiment.

Pointing Error Discriminator

As previously discussed, the pointing error system of the experiment automatically terminates data accumulation if the pointing error exceeds 30 arc sec maximum; the system automatically closes the aperture door if the pointing error exceeds 7 arc min maximum. If for any reason either of the *pointing error system* discriminators should fail and continuously but erroneously indicate a pointing error exceeding 30 arc sec or 7 arc min, the observer can override either of these signals to continue operation of the experiment. By switching the "auto door" switch to the override position, signals for both 30 arc sec and 7 arc min are inhibited. The observer can continue operation of the experiment but must monitor the operation to ensure that data accumulation is stopped manually if the pointing error exceeds 30 arc sec and that the aperture door is closed manually if the pointing error exceeds 7 arc min.

Internal Alignment or Pointing Sensor Failure

The internal occulting disk is normally aligned automatically by the closed loop servo system. If the closed loop servo system should fail, the observer may select manual alignment by moving the align switch to the disk manual position. With the align switch in the manual position, the D_4 error is read out on the pointing error meters and the "WLC

Table 6

RF COMMANDS FOR UNATTENDED AND UNMANNED OPERATIONS, WLCE

1. Door open
2. Door close
3. Main power on
4. Main power standby
5. Main power off
6. Thermal on
7. Thermal off
8. Primary converter select
9. Secondary converter select
10. Mode fast scan
11. Mode standard
12. D_4 Automatic override
13. Internal alignment, up
14. Internal alignment, down
15. Internal alignment, left
16. Internal alignment, right
17. Internal alignment, stop

Table 7

SWITCH POSITIONS FOR UNATTENDED AND UNMANNED OPERATIONS

Switch	Position
Ground/DAS	Enable
Main power (1)	Standby
Door (2)	Center
Automatic door (4)	Normal
Mode (5)	Standard patrol
Low film inhibit (6)	Normal
Start-stop (8)	Center
Thermal (10)	On
Mirror position (12)	Center
Scale (13)	X10
Align (14)	Pointing
WLC align (16)	Center

align" system is energized, allowing the observer to manually command the disk up, down, left, or right while monitoring the alignment error on the meter.

Recognition of a D_4 alignment problem is possible either by displaying the D_4 error or by monitoring the coronal picture via the *TV system*. If for any reason the outputs from the internal occulting disk to the meter fail, the observer can manually align the internal occulting disk by monitoring the coronal image on the television.

Final pointing of the coronagraph experiment is accomplished by using the *pointing error sensor* on the experiment. Failure of the pointing error sensor system would require that coarse pointing be accomplished by the ATM fine sun sensor and that fine pointing be accomplished by the coronagraph *TV system*. Fine sun sensor readings taken when the experiment *pointing error system* is functional will allow statistical generation of a bias between the ATM fine sun sensor and the experiment *pointing error system*. This bias would then be used to point the coronagraph with the ATM fine sun sensor, and the observer could accomplish fine pointing of the coronagraph using the coronal image on the TV monitor.

To assist the observer in evaluating proper pointing or alignment or both, Fig. 19 presents a series of photographs illustrating the effect on the stray light of system and D_4 mispointings. Several things are to be noted:

- These pictures were made by a balloon-borne infrared version of the ATM White Light Coronagraph, and the residual intensity over the field is the sky brightness present at 35,000 m, the float altitude of the balloon. This sky brightness, of course, will not be present in the orbiting version.

- The interpretation of the photographs is complicated because a periodic pointing error is always present during the exposure due to the balloon guidance system. The magnitude of this error is noted below each frame.

- The effect of the misalignment of the internal occulting disk, D_4, increases the intensity of the stray light in a crescent around the shadow of the external occulting disks, and hence more sharply defines the contrast of the diffraction rings arising from those disks. The clear definition of these diffraction rings provided by the residual stray light crescent provides a positive means of assessing the alignment of the coronagraph: when the diffraction pattern is symmetrically illuminated around the disk image, the instrument is satisfactorily aligned.

Experiment Programmer Failure

A secondary programmer is incorporated into this experiment. If at any time data cannot be accumulated in the *standard patrol, extended standard patrol, fast scan,* or *continuous patrol* modes, it is possible to select the *secondary programmer* through the mode select switch. Data accumulation in the *secondary programmer* mode (see Table 4) must be terminated manually by the observer.

Experiment Power Supply Failure

If the regulated power supply for the instrument should fail, a redundant power supply is available for continued operation of the experiment. Selection of this redundant power supply is possible through the digital address system command number 40123.

Television Mirror Drive System Failure

The TV mirror drive system is designed with redundant drive motors. However, if for any reason the drive motors should fail, a manual mechanism is available to move and lock the mirror in the film-camera position. Actuation must be accomplished during EVA. Figure 17 shows the mirror mechanism in the "normal" position. To move the mirror to the film-camera position the observer pushes in on the handle and turns it as shown in Fig. 20. Figure 21 shows the mirror mechanism in the film-only position. Once the mirror is moved to the film-camera position using this mechanism it cannot be moved back to the TV position.
Note: During ground checkout, the mirror can be moved back to the TV position with switch 12 after the mechanism has been returned to the "normal" position.

Film Break

In the event that the roll of film in the camera breaks, it is possible that the "operate" light will remain on yet the film counter will not advance. The only other single failure that can create this same set of conditions is a failure in the control and display *counter*. Therefore, if the "operate" light is on but the film counter does not advance, the observer should first attempt to reset the film counter on the control and display panel. If the counter will not reset, the counter has failed and experiment operation should continue. However, if the counter does reset and the situation continues, the observer should then operate the experiment while monitoring the counter to determine if only one section (units, tens, hundreds, or thousands) of the counter has failed. Only after repeated resets of the counter and reruns of the experiment can it be determined whether the film has broken.

VI. OPERATIONAL CHARACTERISTICS

The S-052 experiment exhibits certain operational characteristics that do not affect experiment operation if accepted procedures (*Skylab Operations Handbook*, Ref. 4) are followed. Table 8 lists unique characteristics of S-052.

Table 8

UNIQUE S-052 OPERATIONAL CHARACTERISTICS

Characteristic	Remarks
Ready/operate light flash	Occurs only when two modes are initiated within 1 min.
Manual to automatic D_4 disc operation	Power must be interrupted to regain automatic control after manual control has been selected.
Secondary programmer ready light	The ready light remains on during secondary programmer operation. Operate light will not come on.
Secondary power supply select	Main power must be off before selecting secondary power supply.
Aperture door override release	Release of the aperture door automatic close override can only be accomplished by changing switch position *and* turning operate power off.

VII. DEBRIEFING

Debriefing of observers with Principal Investigators will be primarily directed toward questions concerning the overall performance of the experiment and observations of the sun through the various TV displays. The observer will be questioned about any special events that might appear on the data regarding either experiment performance or solar activity.

Should any of the instruments fail or degrade, the observer will be questioned about his diagnosis of experiment operational characteristics before and during failure. He will be asked to discuss possible improvements in experiment, controls, and displays that would allow correction of problems for possible follow-up missions.

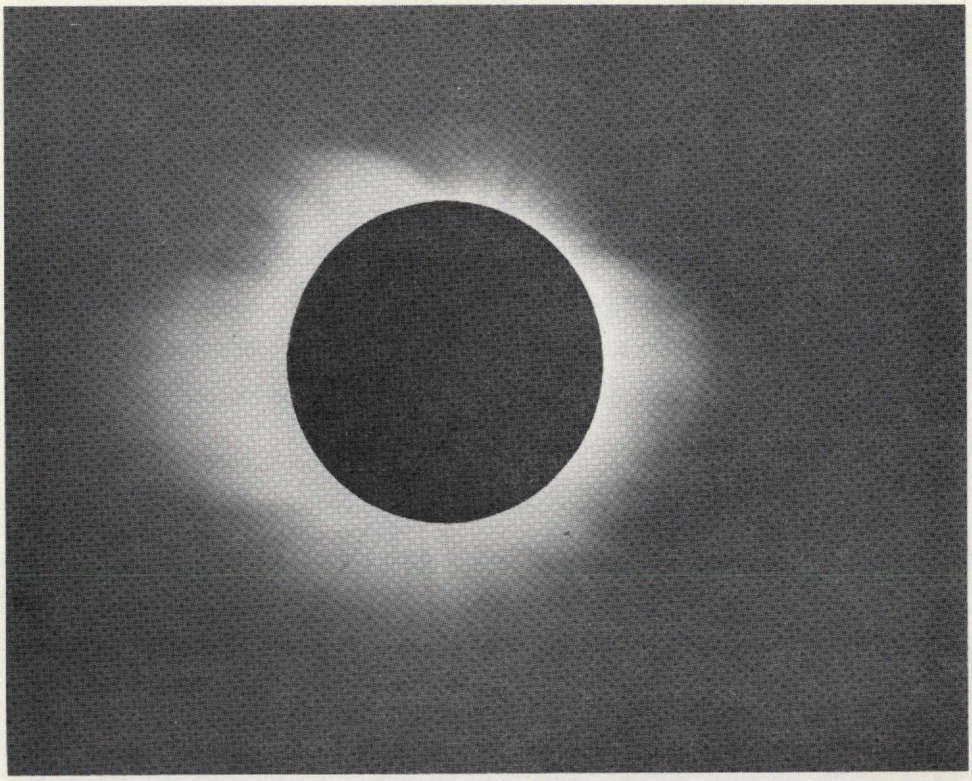


Fig. 1 Eclipse, 31 August 1932

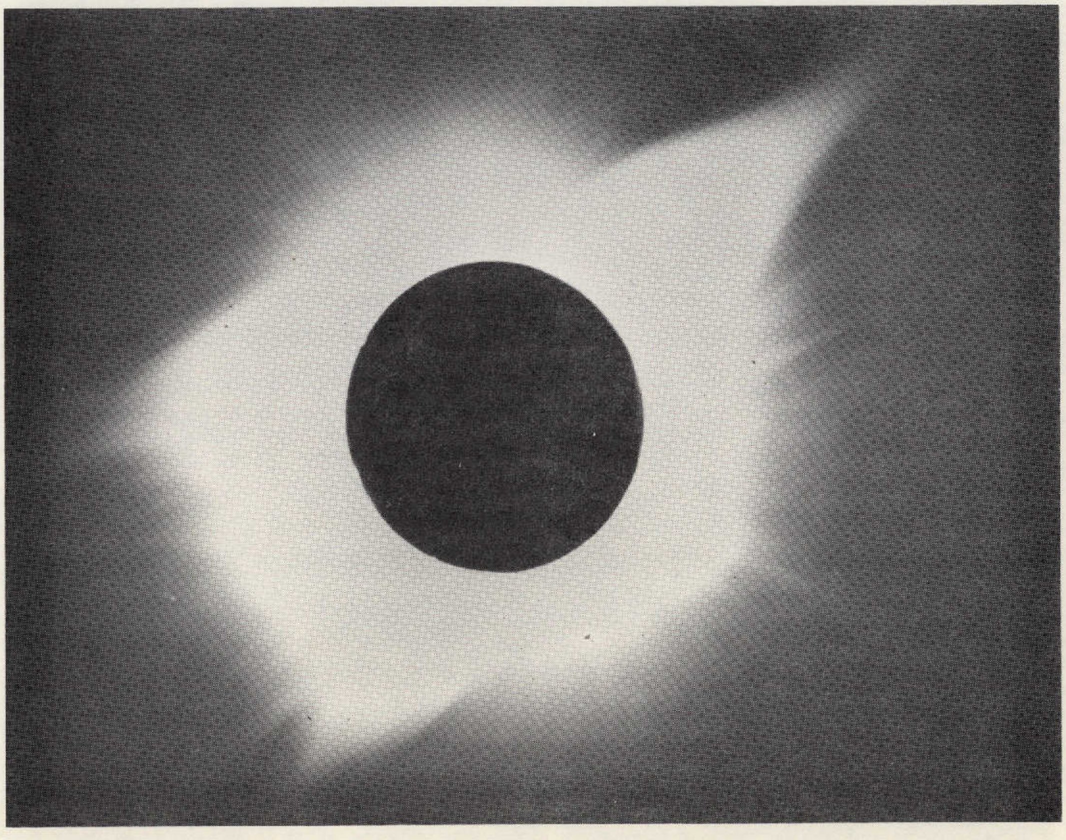


Fig. 2 Eclipse, 25 February 1952

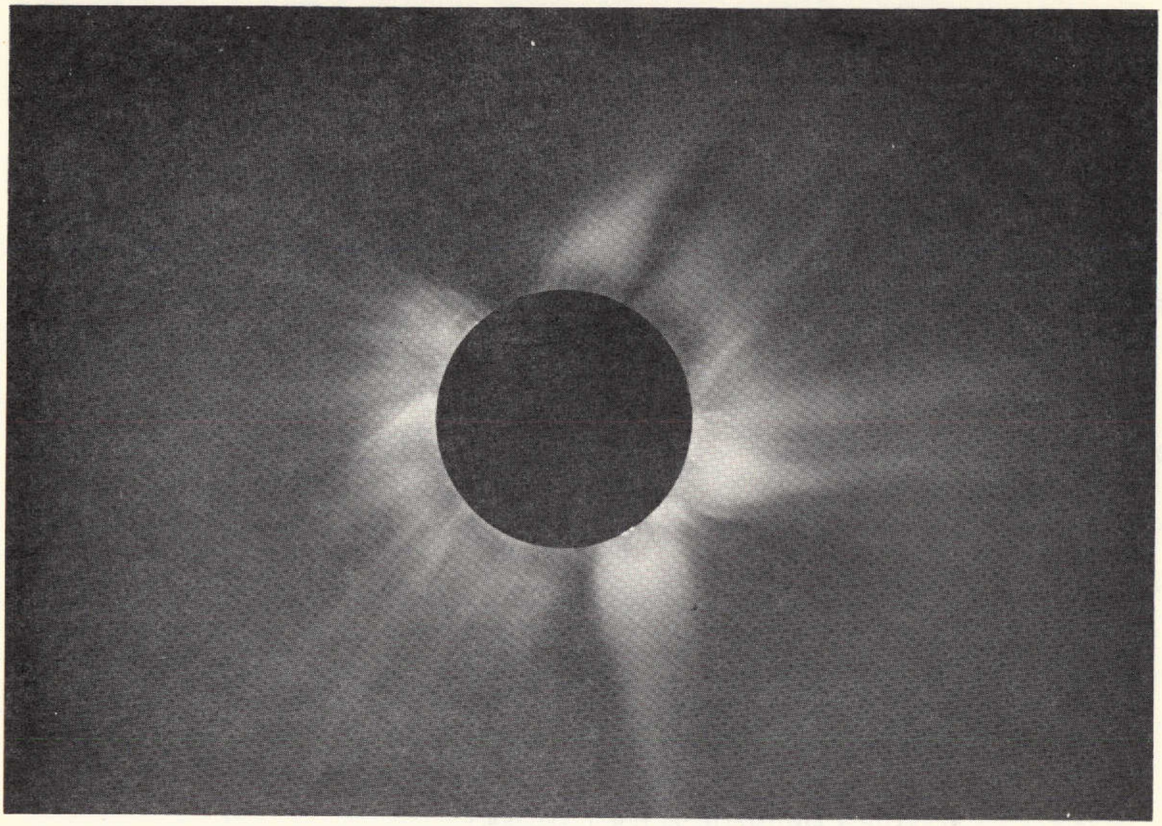
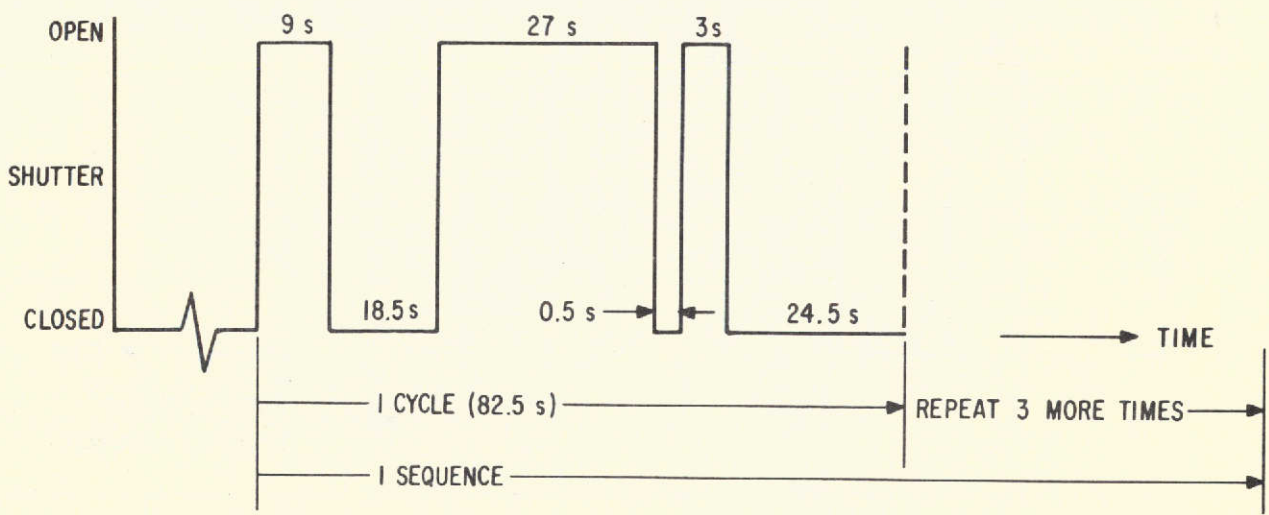
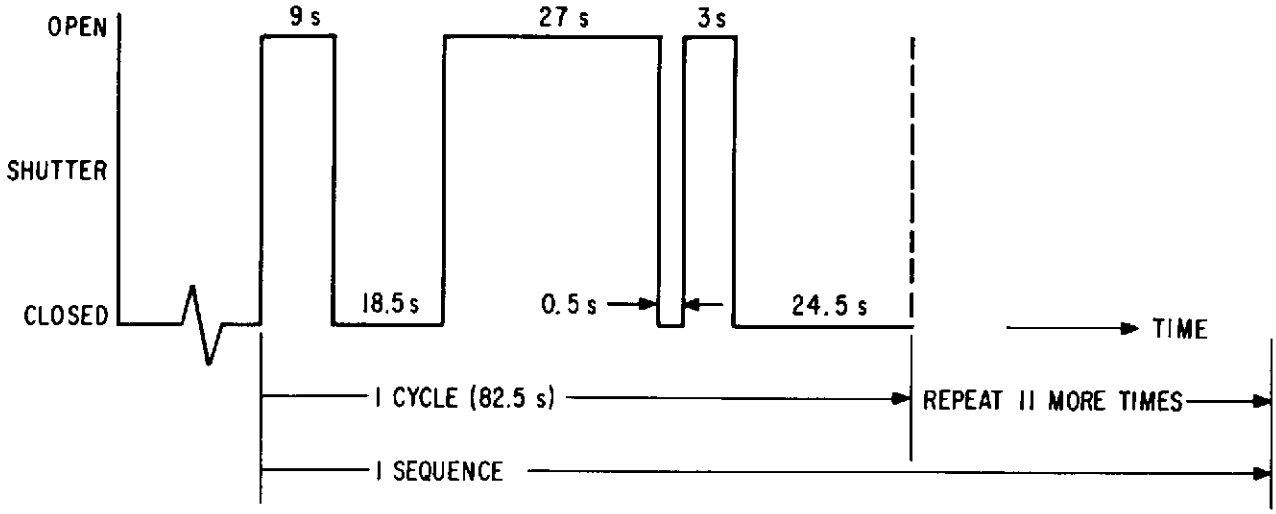


Fig. 3 Eclipse, 7 March 1970



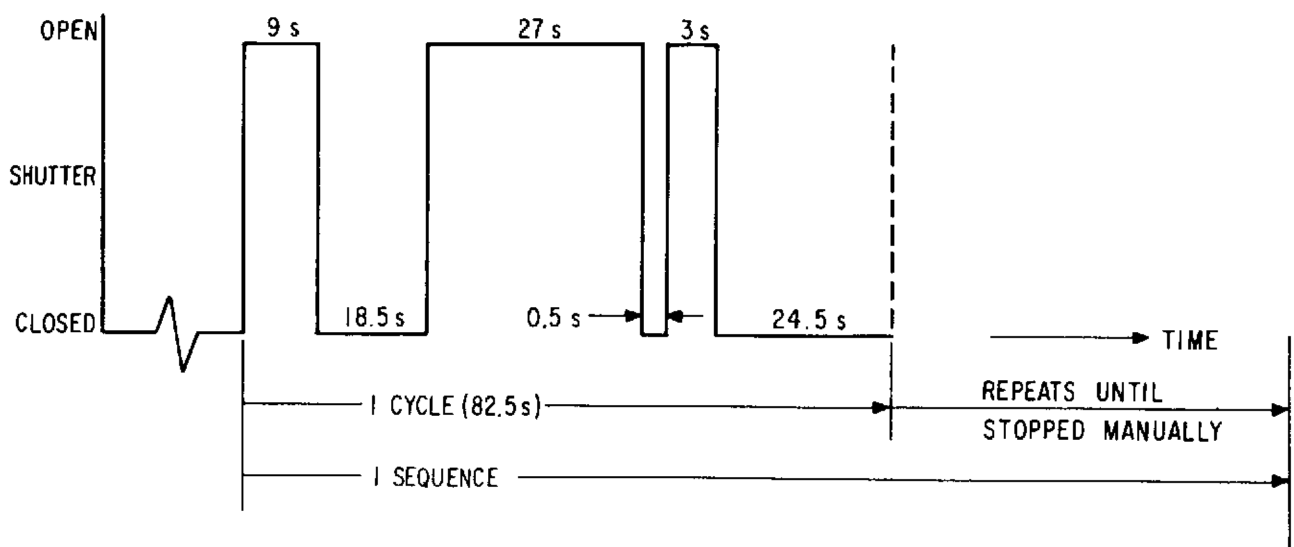
- DURATION-330 S (5.5 MIN.)
- EXPOSURES-12 FRAMES
- POLAROIDS - POS.1 (CLEAR), POS.2, POS.3, POS.4
- STOP-AUTOMATIC AFTER 1 SEQUENCE

Fig. 4 Operational mode sequence, standard patrol



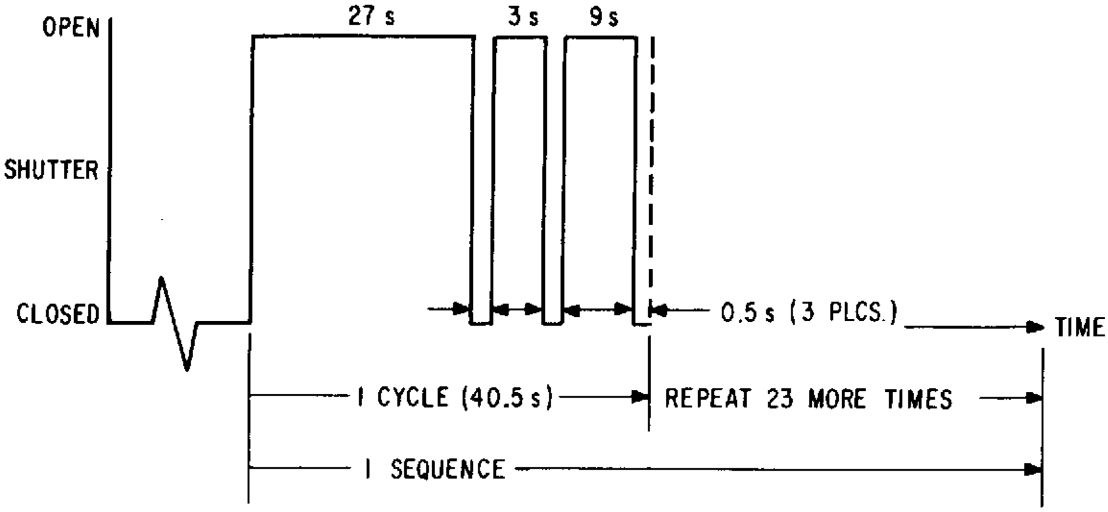
- DURATION – 972 S (16.2 MIN)
- EXPOSURES – 36 FRAMES
- POLAROIDS – POS.I (CLEAR), POS. 2, POS. 3, POS.4
- STOP – AUTOMATIC AFTER I SEQUENCE

Fig. 5 Operational mode sequence, extended standard patrol



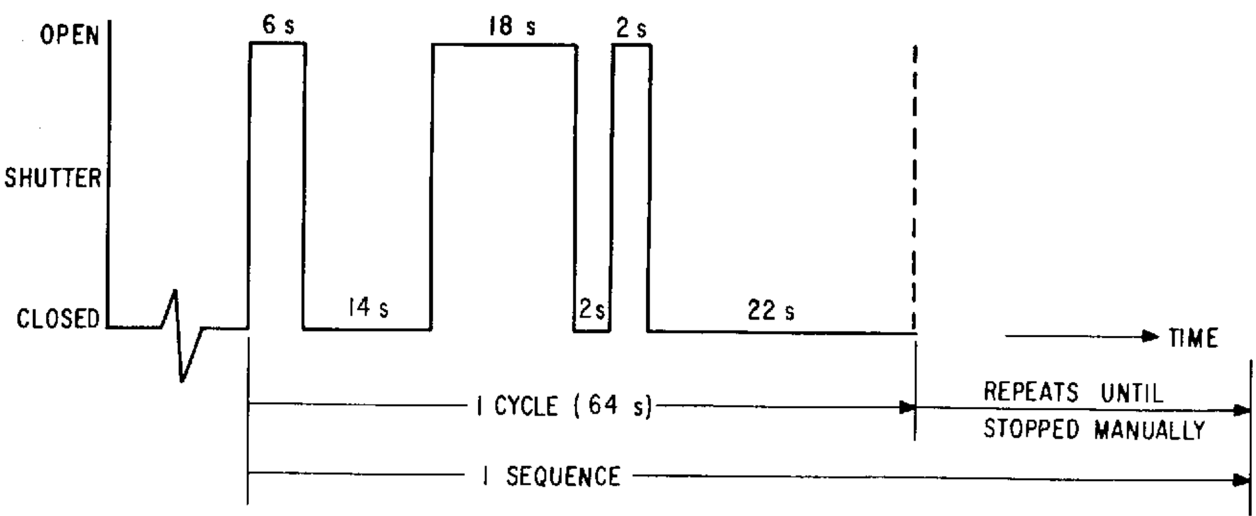
- DURATION - CONTINUOUS UNTIL STOPPED
- EXPOSURES – 3 FRAMES PER CYCLE
- POLAROIDS – POS. I (CLEAR)
- STOP – MANUAL, C & D CONSOLE START / STOP SWITCH

Fig. 6 Operational mode sequence, continuous patrol



- DURATION – 972 S (16.2 MIN.)
- EXPOSURES – 72 FRAMES
- POLAROIDS – POS. 1 (CLEAR)
- STOP – AUTOMATIC AFTER 1 SEQUENCE

Fig. 7 Operational mode sequence, fast scan



- DURATION – CONTINUOUS UNTIL STOPPED
- EXPOSURES – 3 FRAMES PER CYCLE
- POLAROIDS – POS. 1 (CLEAR)
- STOP – MANUAL, C & D CONSOLE MODE SEL. SW.

Fig. 8 Operational mode sequence, secondary programmer

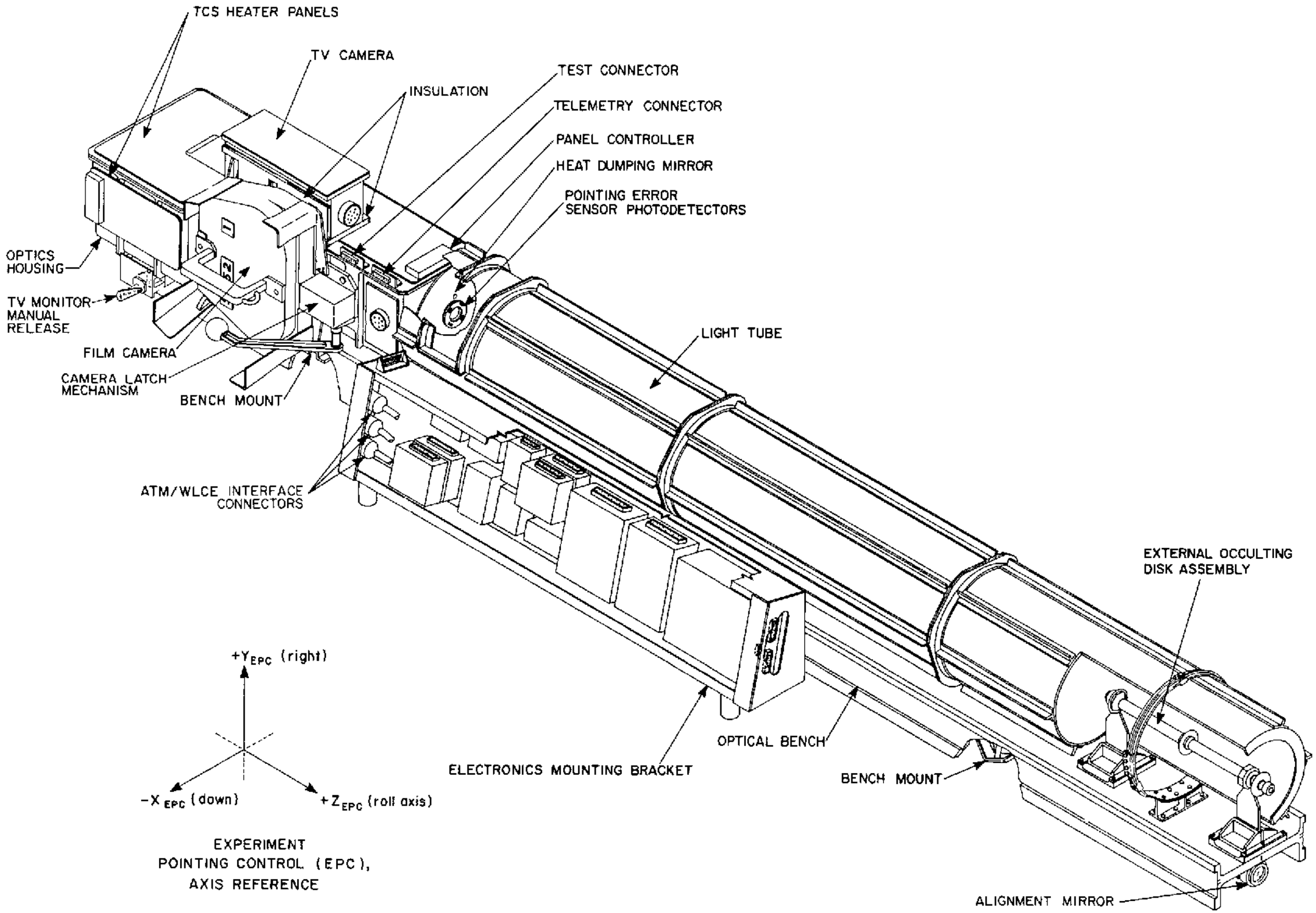


Fig. 9 White Light Coronagraph Experiment

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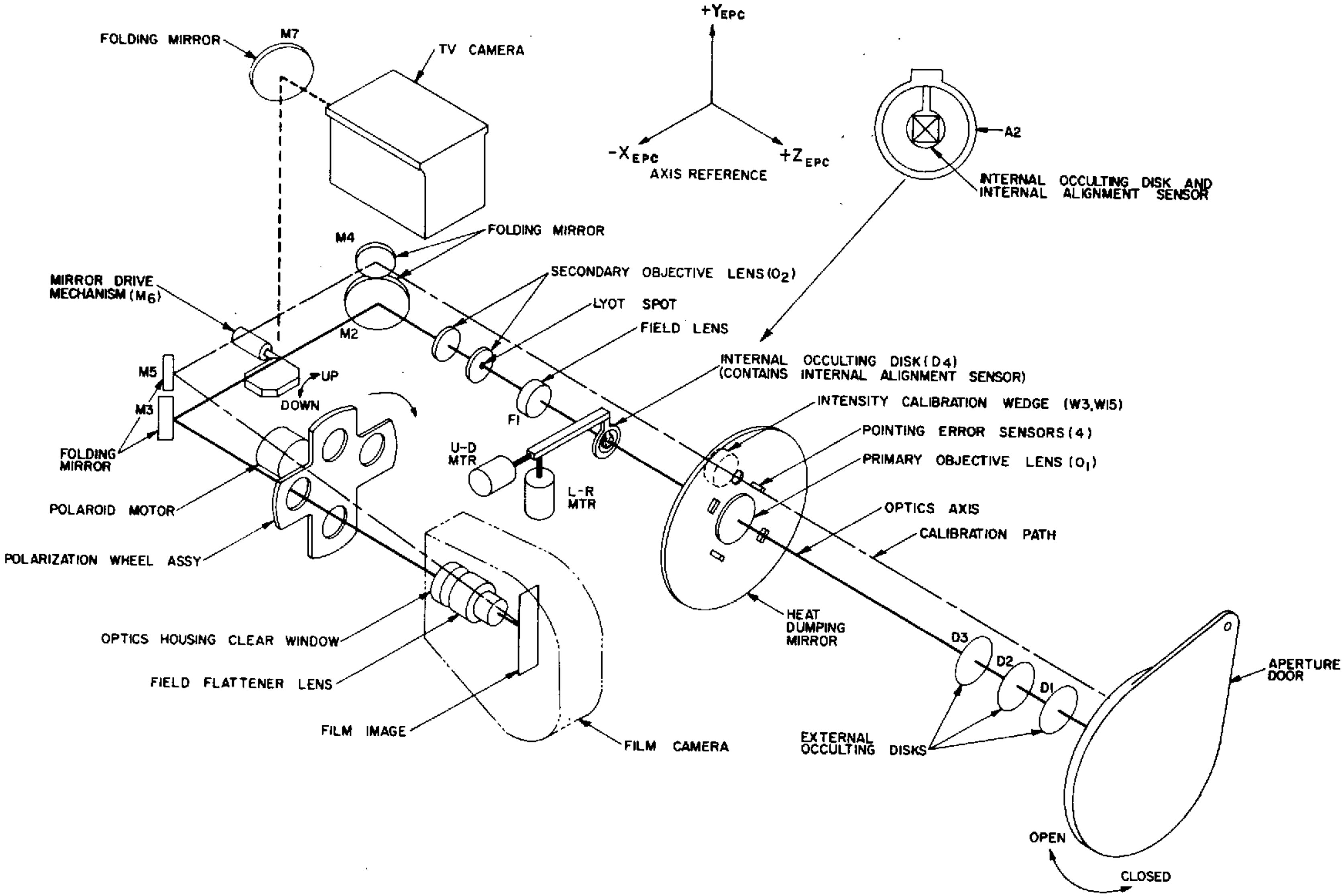


Fig. 10 Schematic of the optical unit for the White Light Coronagraph

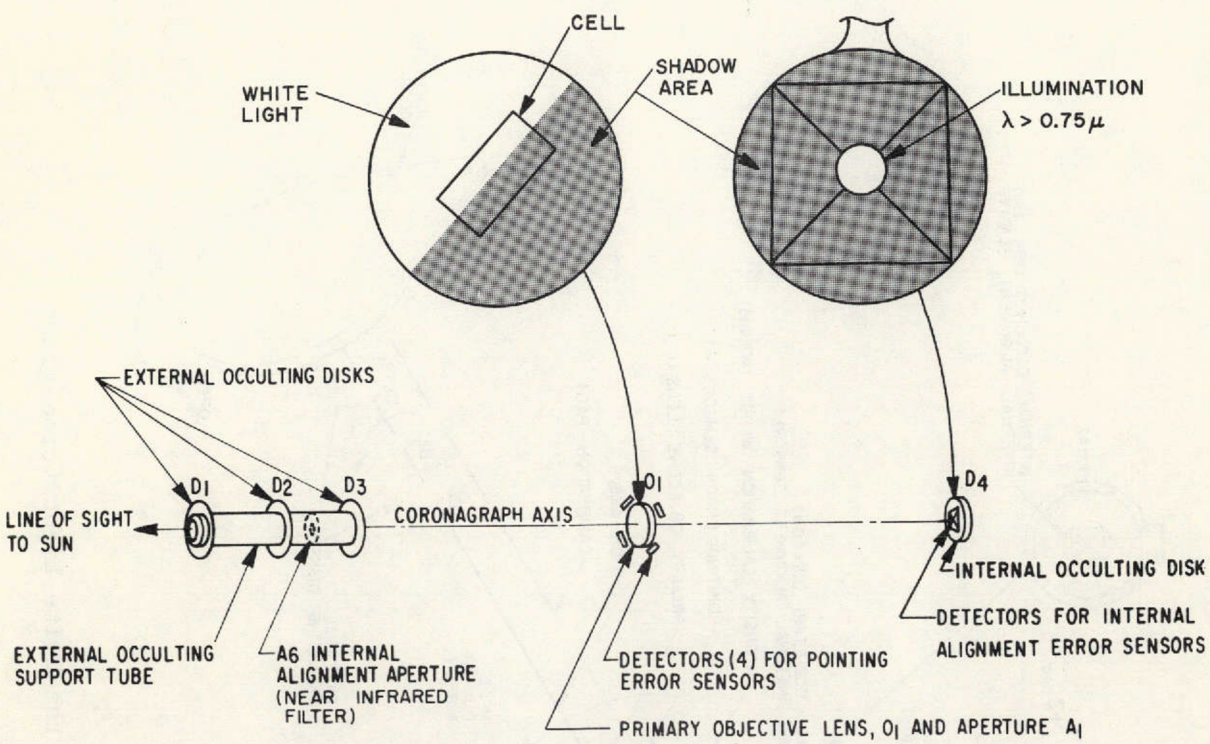


Fig. 11 Schematic of the pointing reference system

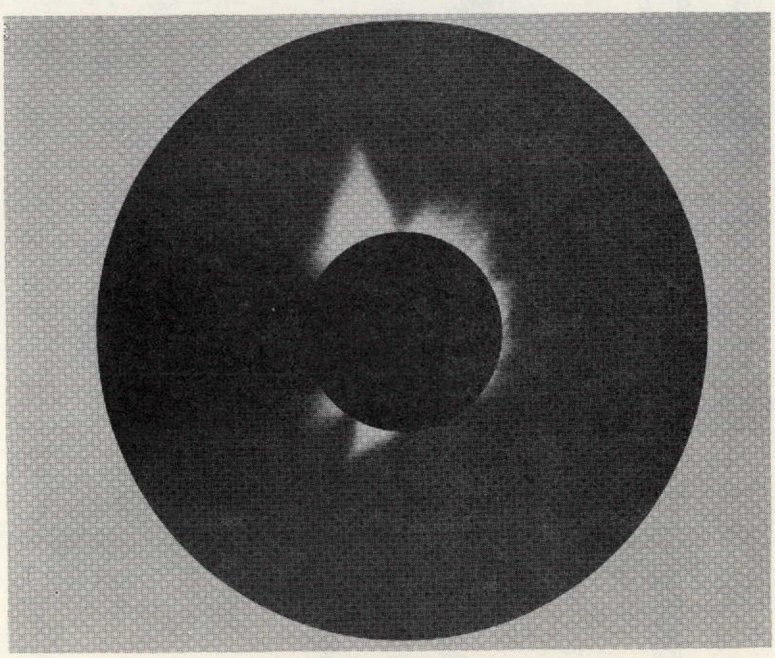


Fig. 12 Simulated TV photograph of 7 March 1970 eclipse

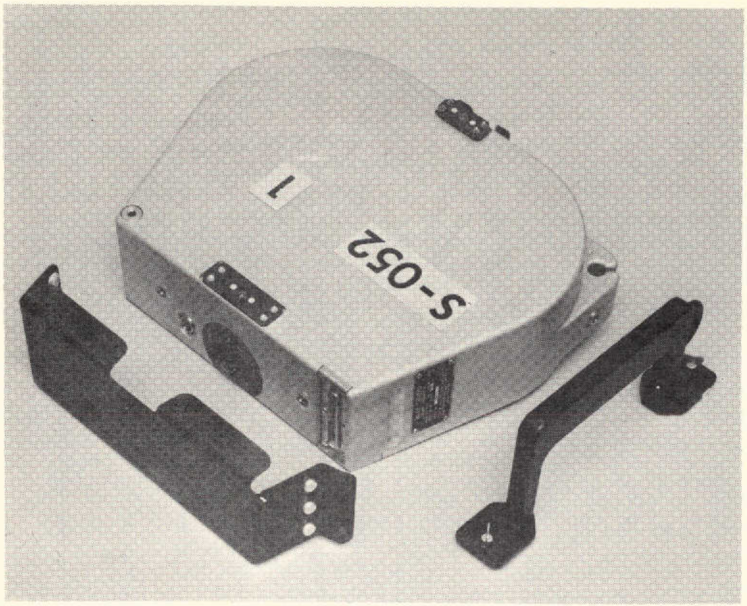


Fig. 13 Film camera, exploded view

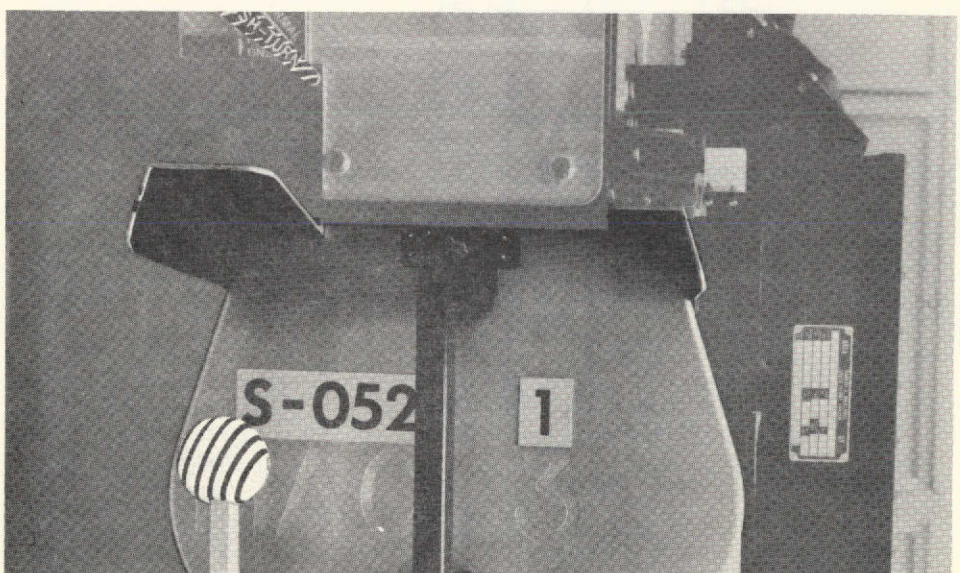


Fig. 14 Film camera on instrument

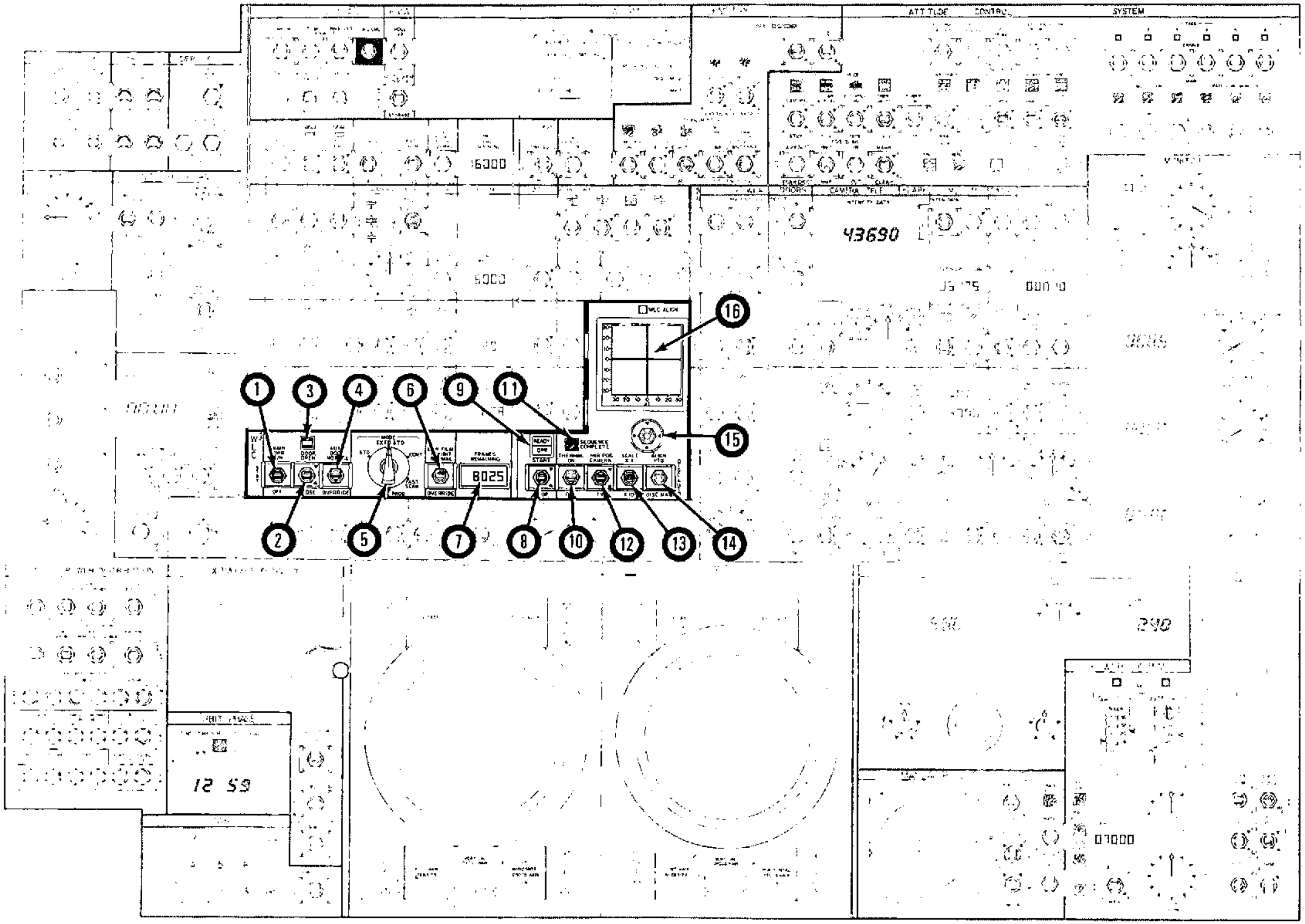


Fig. 15 Control and display panel

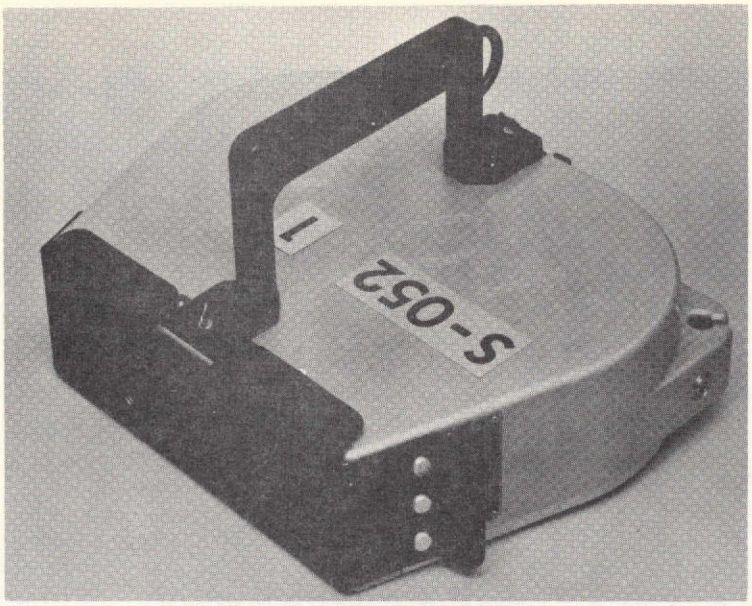


Fig. 16 Film camera with handle and lens cover

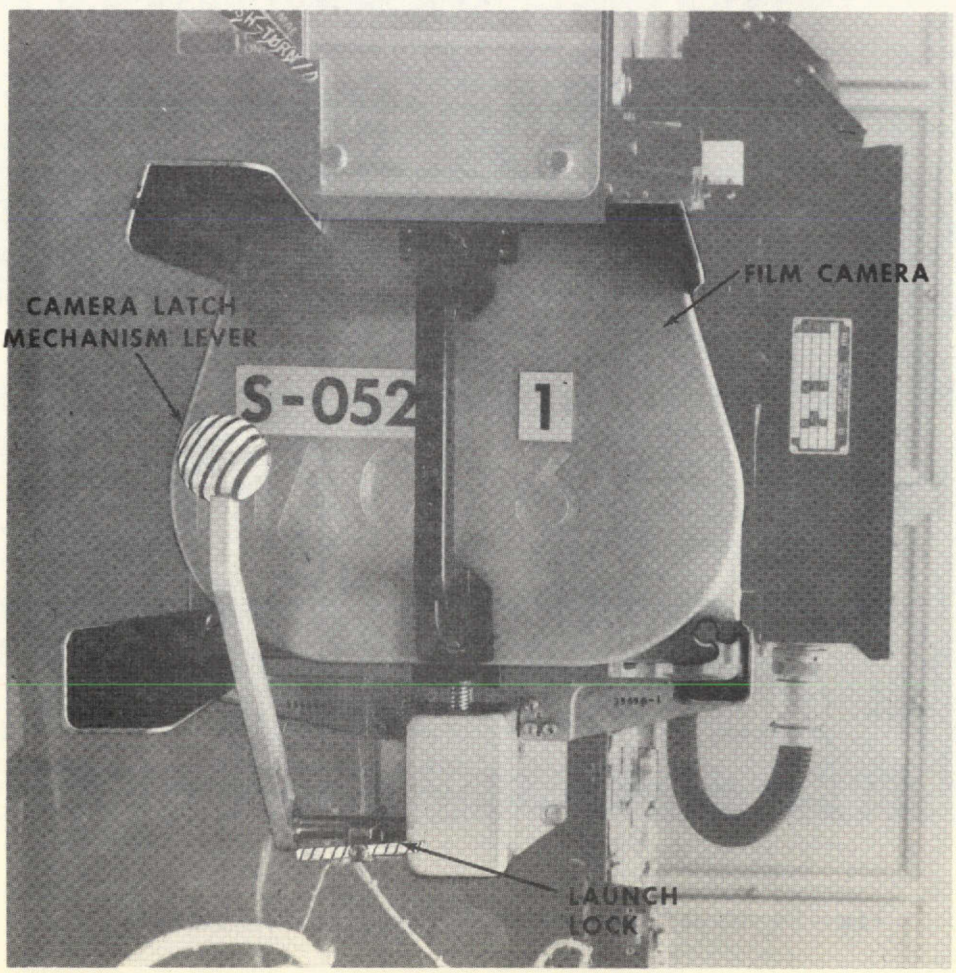


Fig. 17 Film camera on experiment (with callouts)

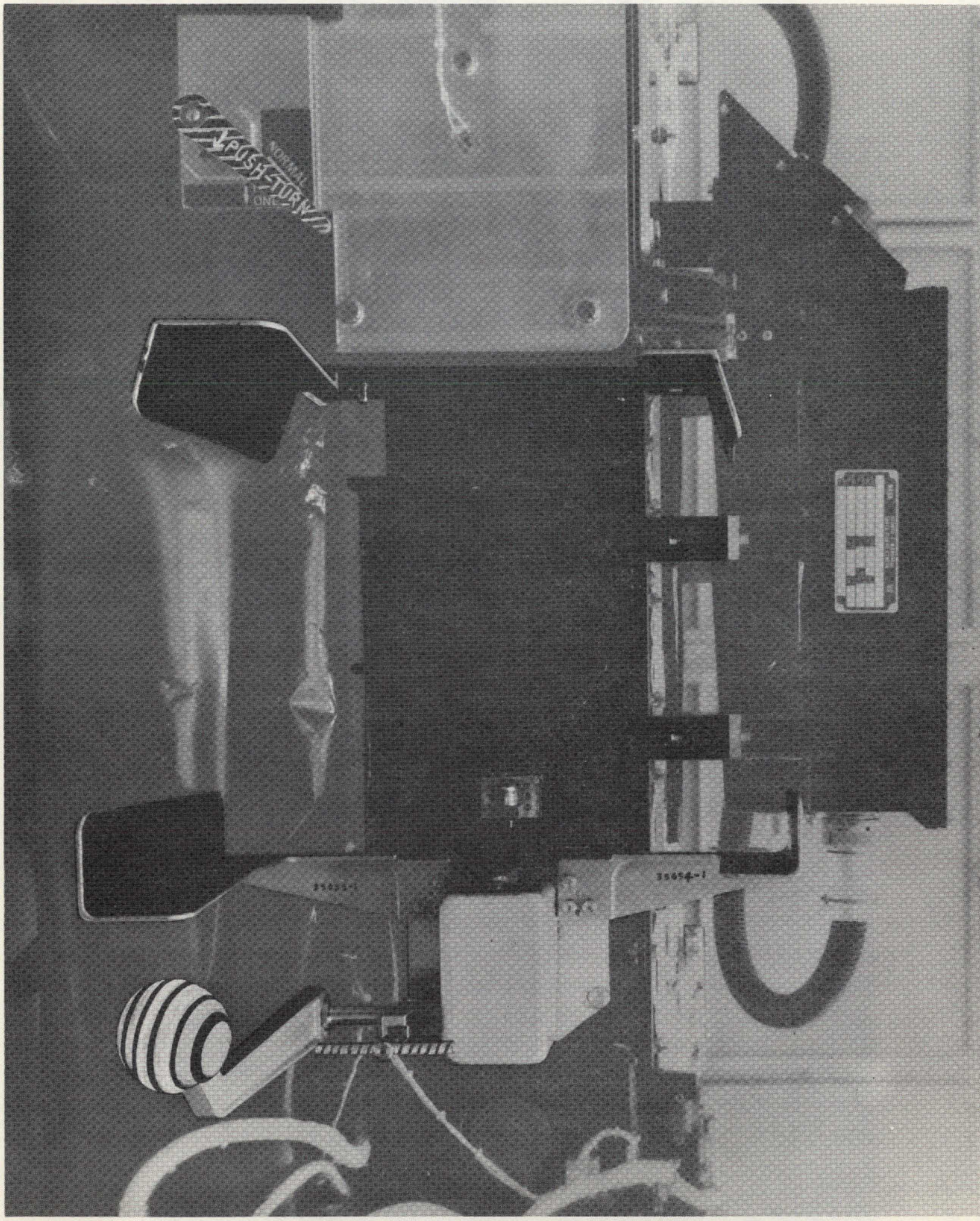
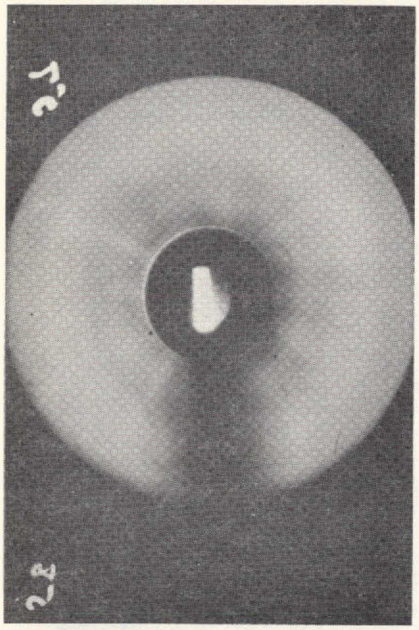
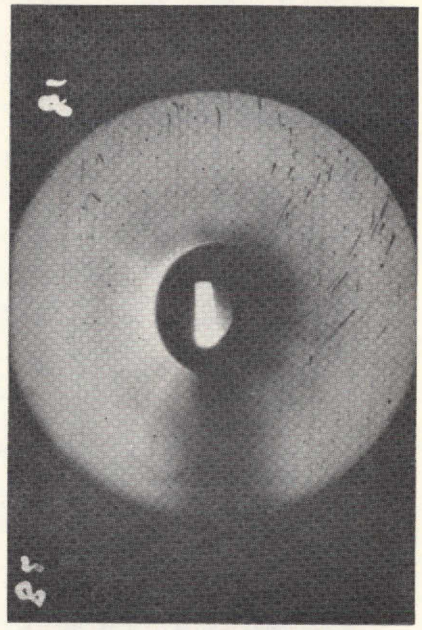


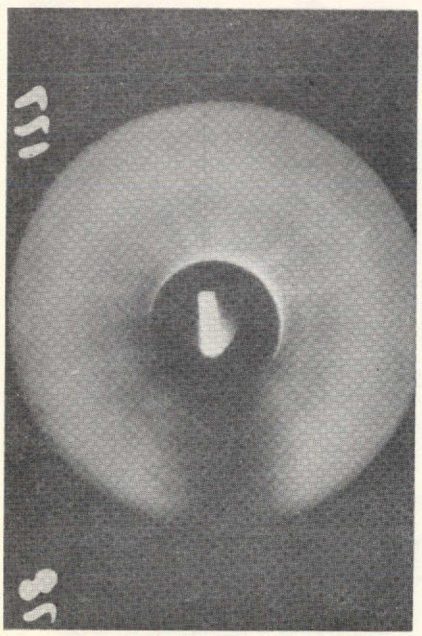
Fig. 18 Experiment ready for camera installation



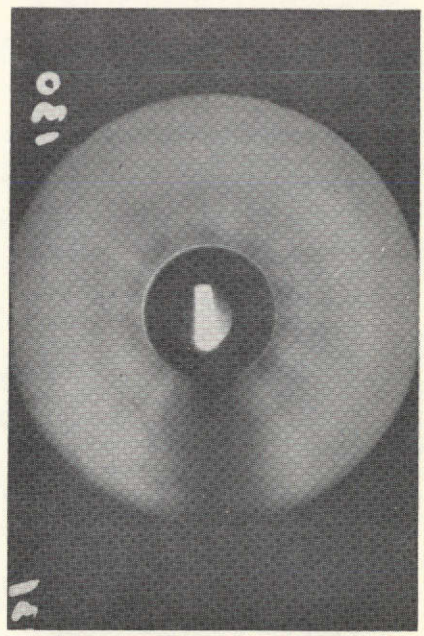
CG Centered; D4 6 steps misaligned
Pointing Errors; Elevation 12 sec;
Azimuth 17 sec.



CG Centered; D4 30 steps misaligned
Pointing Errors; Elevation 45 sec;
Azimuth 7 sec.



CG 66 sec mispointed; D 4 centered
Pointing Errors; Elevation 30 sec;
Azimuth 30 sec.



CG Centered; D4 centered
Pointing Errors; Elevation 50 sec.
Azimuth 77 sec.

Fig. 19 Stray light photographs

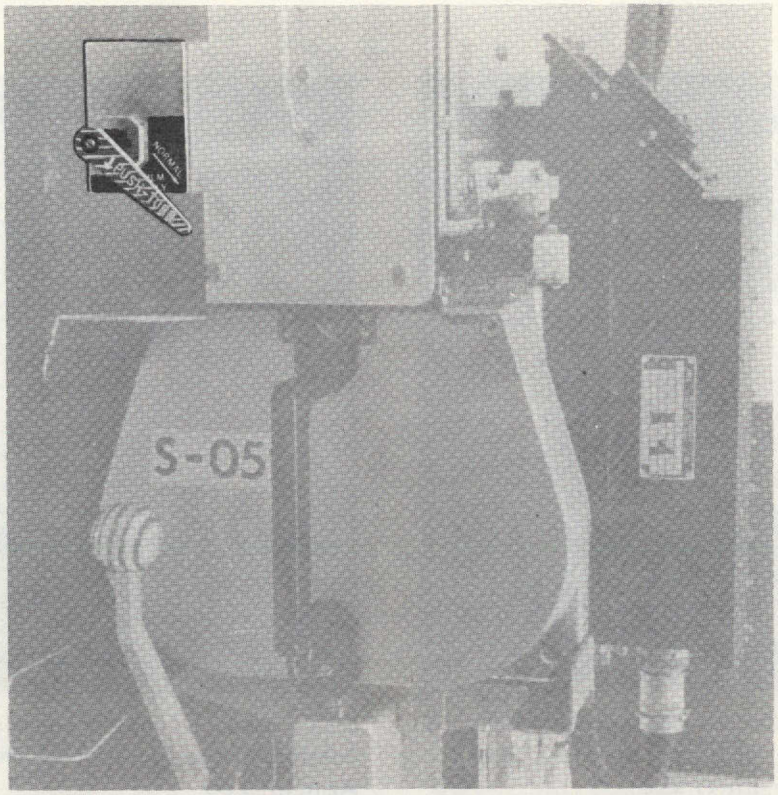


Fig. 20 TV mirror mechanism in normal position

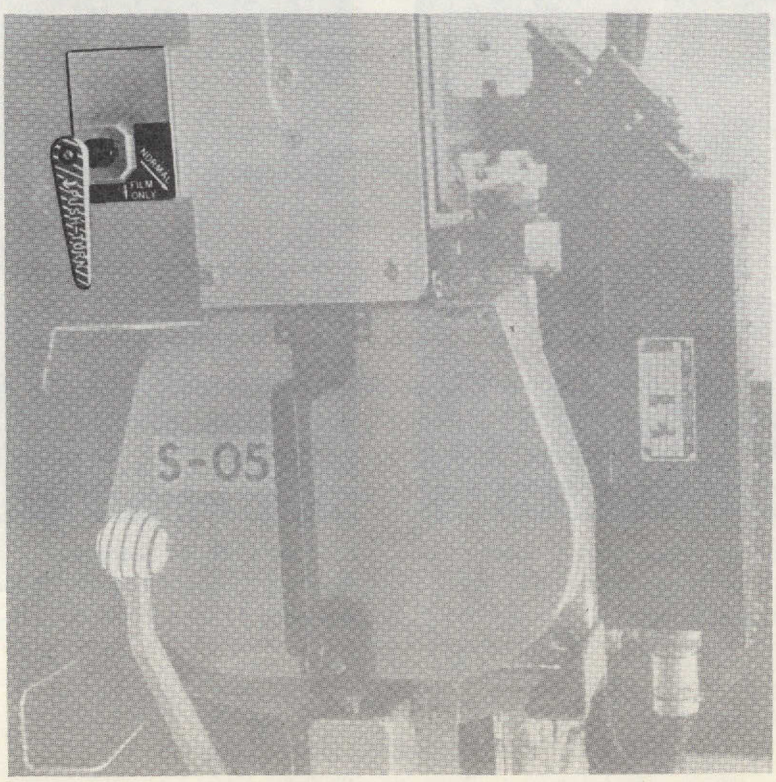


Fig. 21 TV mirror mechanism in film only position

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5. Manned Spacecraft Center, 1967: *Skylab Operations Handbook, Apollo Telescope Mount;* Vol. II, *Systems and Experiments, Operating Procedures*; MSC Document, 247 pp. (26 April).